Introduction

The Montana Inventory and Monitoring Project (Diversity Monitoring) was proposed in response to a recognized need for baseline information on a variety of non-game species (Montana Comprehensive Fish and Wildlife Conservation Strategy (CFWCS), Montana Fish, Wildlife, and Parks 2005). This recognized need included the need to develop a long-term inventory and monitoring program that would:

(1) simultaneously provide information on a diverse suite of faunal groups,

(2) provide baseline information on species' distributions, site occupancy rates, and detection probabilities that can be used to inform current species conservation status ranking and management efforts,

(3) evaluate methodologies and preliminary estimates of detection and site occupancy rates in order to refine survey protocols for future monitoring efforts,

(4) establish a baseline of information that can eventually be used to assess changes in distribution and status over time related to changes in habitat and/or management efforts,

(5) identify immediate or future research needs for individual species, species assemblages, or habitats,

(6) identify gaps in species' ranges across the state and potentially create maps identifying patterns in individual or collective occupancy rates of species across the state.

Background

Maintaining a diverse assemblage of native species is important for maintaining the ecological relationships and ecological services on which all species depend. Benefits of maintaining biodiversity may include protecting food web dynamics, safeguarding against disease outbreaks, maintaining high quality range and forest land, and providing harvestable plants and animals (Allan and Flecker 1993). Everett et al.(1994), Noss and Cooperrider (1994) suggest that monitoring biodiversity is an important element of ecosystem management and can be incorporated into an adaptive management approach for land management.

In Montana, very little information exists on the status and distribution of a diverse assemblage of vertebrates, including small mammals, amphibians, reptiles and bats (Montana Fish, Wildlife, and Parks 2005). Completing baseline statewide assessments is essential to determining appropriate steps for conserving these species.

The goal of this project was to develop and refine survey, inventory, and monitoring protocols in order to better understand the distribution, status, and habitat requirements of species or groups of species identified as most in need of inventory within Montana (Montana Fish, Wildlife, and Parks 2005). It is our hope that development of effective and standardized methodologies will allow other state, federal, tribal, and private entities to follow our lead and gather compatible data. In addition, standardized protocols will set the stage for future work.

Methods

Montana encompasses an area of 381,154 square kilometers and is too large to survey systematically in a single year. Thus, surveys were conducted over three years: northeast in 2008, southeast in 2009, and west in 2010 (Figure 1). Six crew members were hired each year to work in teams of two. Table 1 summarizes the materials used by each crew for each survey type.

Sample Site Selection

We used a stratified randomized sampling design to select survey sites across public and private lands statewide in order to make inferences about occupancy and detection rates in various habitats within the known range of individual species. The sample site, or unit of study for this project, was defined as a quarter of a USGS 1:24,000 scale topographic quadrangle; there are 11,265 potential quarter-quadrangles available for sampling across the state (Figure 1). Quarter-quads were divided into primary and oversample groups to give crews flexibility in eliminating those with limited access, inappropriate habitat, or inadequate habitat for surveys. Individual quarter-quads varied slightly in size, but were generally 3 x 4.3 miles in size (Figure 2). Quarter-quads that were entirely contained in water or within Bureau of Indian Affairs or National Parks land were not included as potential sites to be sampled for this study. All quarter-quads that were sampled were surveyed on multiple occasions over a period of several days based on a strict schedule (Figure 3). Specific survey locations within each quarter-quad varied depending on the faunal group that was the focus of each survey type (Figure 4).

Small Mammal Trapline Surveys

Three potential survey sites were placed within each q-quad: one within a riparian cover type, and one within each of the two most dominant cover types. If the two most dominant habitat cover types were extensively modified by humans (e.g., hay field and cropland), only one of the modified habitats was surveyed. Survey locations were prioritized based on: (1) their accessibility, i.e, public land or private land where permission had been granted; and (2) the size of the cover type patch. Large patches were prioritized for sampling to limit influence from adjacent habitat types.

Traplines were oriented in habitat cover type patches so that they were all within relatively uniform habitat structure. Each 90-meter line was composed of 10 stations spaced 10-meters apart. Each station had 1 or 2 Victor mouse traps, 1 museum special trap, 1 pitfall trap, and 1 Sherman trap; station numbers 2 and 9 had a rat trap instead of a second mouse trap (Figures 5 and 6). Traplines were allowed to weave or arc in order to remain within a single habitat cover type. Pitfall traps were dug into the ground and placed flush with soil so that animals were not alerted to their presence; when possible, pitfall traps were placed to take advantage of natural fences in the terrain like logs, rocks and drainages. Snap traps were baited with peanut butter and Sherman traps were baited with sweet feed mix. Snap and Sherman traps were placed in natural runways approximately 1-meter from the central pitfall trap rather than at exact right angles as indicated in the example diagram (Figure 5).

All traps were set in the evening as close to dark as logistically feasible and checked each morning as early as possible to minimize animal stress and mortality. Traps were sprung and left closed each morning in order to prevent incidental mortalities of non-target species during daylight hours. Surveyors wore latex gloves and HEPA masks when handling live and dead animals and checking traps. Hand sanitizers were used after handling traps. To handle live captures in Sherman traps, a plastic bag was placed over the trap opening and the animal was shaken into the bag, sexed, weighed, measured, marked and released. Measured attributes included total length (nose to tail tip), tail length, hind foot length (include claws), and ear length.

The following were kept as museum voucher specimens at each q-quad: (1) the first specimen of deer mouse, montane vole, and meadow vole; (2) all snap trap captures of other species regardless of number captured; (3) all shrews; (4) any animal for which species identity was uncertain; (5) one example of each species captured. When necessary, live animals were euthanized by placing a cotton-ball dabbed with a small amount of isoflurane into the opposite corner of the bag until 15 or more minutes after the animal had stopped breathing. Vouchered specimens were placed in an individual zip lock bag with a fully completed museum voucher tag. All specimens from each trap line were placed in a larger bag labeled with the trapline (site) name and number and quarter-quad name and number. After the three nights of trapping in a quarter-quad, all bags from each trap line were placed in a bag labeled with the quarter-quad name and number. Vouchered animals were placed on ice or in a refrigerator. All vouchered species were later sent to the University of Montana, Missoula to be prepared as museum voucher specimens by work study students. Species identification was verified by Paul Hendricks, Montana Natural Heritage Program Zoologist, and Dave Dyer, Curator of the Phil Wright Memorial Zoological Museum.

Variables recorded at each small mammal trap line included both categorical and quantitative descriptions of habitat and conditions during the survey (Appendix I - Small Mammal Trap Line Data Sheet). Digital photographs of each trap line were taken from a vantage point that allowed the trap line flags to be seen in the context of the surrounding habitat.

Bat Acoustic Detector Surveys

Each major habitat cover type within each quarter-quad was sampled using a Petterson D240x acoustic detector attached to an Iriver MP3 player/recorder (typically the iFP-899 model, but also the H320 Zoom model). Survey locations were prioritized by the following criteria: (1) representation of all major cover types; (2) readily accessible locations on public land or on private lands where permissions to survey were received; and (3) wetland and native terrestrial cover types; and (4) relatively large habitat patches where the detector could be placed inside the edge of the habitat patch by 100 meters or more. Detectors were spaced a minimum of 400 meters apart in order to ensure independence between surveys.

Variables recorded at each acoustic survey site included both categorical and quantitative descriptions of habitat, quality of the habitat, and potential threats to the habitat (Appendix I - Bat Acoustic Survey Data Sheet).

Acoustic detectors and recording devices were housed inside weatherproof containers that were mounted on conduit attached to a piece of rebar pounded into the ground as an anchor point (Figure 7). Detectors and recorders were turned on shortly before dusk to capture the first emerging bats of the evening and were collected each morning at various times after sunrise. Batteries in the detectors and/or recorders sometimes died during the deployment period, especially on cold nights. However, we feel that the detector/recorder units consistently recorded for the first six hours after deployment. Detectors were collected each morning and .wav files were downloaded to a laptop computer and attributed with q-quad, location, basic habitat descriptions, and other survey information.

At the end of each field season, calls were analyzed using Sonobat 3.0™ (SonoBat 2012), which has automatic species recognition capabilities using a hierarchy of discriminate function analyses based on up to 72 different call characteristics (e.g. duration, upper slope, lower slope, maximum frequency). However, this software package does make regular errors in species identification. Thus, In order to verify the call identification results of this automated program, at least one call sequence per species per site was confirmed by hand by Susan Lenard, Montana Natural Heritage Program Zoologist.

The Petterson D240x detector settings were: normal, time expanded output, high gain, auto trigger, low trigger level, high frequency trigger source, and 1.7 seconds of real-time recording. The H320 Zoom recorder settings were: File Format = MPEG layer 3; Encoder bitrate = 160 kilobytes per second; Frequency = 44.1 kHz; Source = Line In; Channels = Mono; File Split Options = N/A; Prerecord time = 1s; Clear Recording Directory = N/A; Clipping light = N/A, Trigger settings = repeat, stop, 1s, -25db, 0s, -40db, 2 s, 1s; Automatic Gain Control = N/A; AGC Clip Time = N/A.

Amphibian and Aquatic Reptile Surveys

All standing water bodies present within each quad or found incidentally while in the field were surveyed when they were accessible. If no standing water bodies were found on the topographic maps, accessible lands were surveyed for water by driving roads or hiking major trails to examine areas of low topographic relief or backwaters of streams that might provide lentic breeding habitat. If too many suitable water bodies were found within each quarter-quad, those likely to have more suitable habitat were prioritized for survey.

Each water body surveyed within a quarter-quad lentic site was considered an independent survey location. Surveys were considered independent by individual observer as well. Timed visual encounter and dip net surveys were conducted in all portions of the water bodies less than 50 cm in depth. If little emergent vegetation was present, then observers were asked to carefully examine shallow water environments for the presence of eggs, larvae, or post metamorphic animals. Areas with extensive shallows required systematic searches and dip netting while wading through the area on evenly spaced transects (Figure 8). In areas with dense emergent vegetation, observers intensely sampled the area with a dip net. At sites with steep shorelines, visual searches and dip netting were performed. If multiple waterbodies were surveyed within a 200-meter radius of an existing start point, those waterbodies were considered as part of the original survey. Digital photographs of each site were taken from a vantage point that allowed the entire site to be seen in the context of surrounding habitats.

Variables recorded at each lentic survey site included both categorical and quantitative descriptions of existing habitat, the origin and quality of the habitat, and potential threats to the habitat (Appendix I - Lentic Site Survey Data Sheet).

Voucher specimens of amphibians and reptiles were collected if the record filled a significant data hole or extended the species' known range or if the identity of the species was uncertain, e.g., Bufo species tadpoles found in eastern MT. For amphibian and reptile eggs, and newly hatched amphibians, individuals of the same species were placed together in a small jar containing 10% buffered formalin. Amphibian larvae that were collected as vouchers were first placed in a Tricaine (MS-222) solution (1 teaspoon per liter of H_2O) until they failed to respond to a mechanical stimulus. They were then placed in a 10% buffered formalin solution for fixation and storage.

Amphibian adults and juveniles collected as voucher specimens were euthanized by placing a small bead (3/4") of extra strength Orajel (20% Benzocaine active ingredient) on a finger and spreading it out over the thighs, abdomen, and top of the head of the individual(s) collected. The animal was then placed in a Ziploc bag in a darkened area (e.g., a box) for 10-15 minutes until the animal failed to respond to a mechanical stimulus. The brains of the animals were then injected with a 10% neutral buffered formalin solution in order to stop the animal's central nervous system. Animals were then placed in a fixing container containing 10% neutral buffered formalin. Body cavities of large individuals were injected with 10% buffered formalin using a syringe. All specimens remained in 10% buffered formalin until the end of the field season. At the end of the field season specimens were removed and washed in a jar of water (preferably running water) for 48 hours. For long-term storage, individually tagged specimens were placed in a jar containing 70% ethanol.

Reptile Surveys

Survey sites were located by visually assessing each quarter-quad on 1:24,000 scale topographic maps for areas with noticeable topographic relief (Figure 9). Rock outcrops and cliff faces often constitute boundaries between substrate types that differ in erodibility and rock strata. These areas often provide underground chambers or collapsed areas that serve as cover or even hibernacula. Other factors considered in survey site selection included: (1) site accessibility, i.e., public land or private lands where permission was received; (2) size of the rock outcrop (the larger the size, the better); and (3) aspect of the survey location, with higher priority given to south facing sites than north facing sites. When time allowed, field crews attempted to survey four or more rock outcrops per quarter-quad.

Each rock outcrop or coulee rim surveyed was considered an independent survey location. Surveys were considered independent by individual observer as well. If a rock outcrop or coulee rim was large, then multiple survey locations were made using an approximate size of 400 x 100 meters, based on natural breaks such as a drainage or area with reduced amounts of cover objects. If rock outcrops or coulee rims were not present within a quarter-quad, then transects through a dominant cover type were substituted as survey locations.

Timed visual encounter surveys were conducted in all portions of the rock outcrop by slowly moving through the area. Rocks were visually examined at distances from 0 to 15 meters. Objects providing cover, such as logs or rock slabs were lifted. Potato rakes were used to probe rock crevices while listening and watching for animal movements.

Digital photographs of each site were taken from a vantage point that allowed the entire site to be seen in the context of surrounding habitats. Variables recorded on datasheets at each reptile survey site included categorical descriptions of existing habitat and conditions of the survey that could have influenced the probability of detecting the species (Appendix I - Reptile Survey Data Sheet).

Voucher specimens of reptiles were only collected if the record filled a significant data hole or extended the species' known range or if the identity of the species was uncertain. Protocol for preserving voucher specimens of reptiles followed that of the amphibian preservation protocol. Large snakes and turtles were not euthanized nor were they collected as voucher specimens unless found dead (e.g., road kill).

Incidental Captures and Observations

During surveys for other taxa, crews recorded all non-target animals that could be identified to species. Number of individual and any notable behavior, such as courtship or nesting, was also recorded. (Appendix I - Incidental Data Sheet). Incidental animals encountered that could not be identified to species level were collected as voucher specimens for later identification purposes. No migratory birds were collected.

Millipedes, slugs, and snails were placed directly into vials containing 70% ethanol. No more than two animals of each species were placed in containers. After death (6-24 hours) any mucus exuded was gently brushed off and the animal was placed in 95% ethanol for 24-48 hours. Any remaining mucus was then brushed/washed off again and a dissecting pin was used to perforate the animal along its length so that ethanol would penetrate the body. Animals were then placed in 70% ethanol for long-term storage so they could be used as museum vouchers and as a source of tissue for genetic analyses.

Data Management

Each survey crew used standardized data sheets to record information and describe variables for each type of survey (Appendix I - Data Sheets). At the end of each day, crews used laptop computers to record data into a Microsoft Access database (Figure 10). At the end of the field season, each of the crew databases were checked for errors and missing information. Final data were then appended to a master database.

Once all data were compiled for all years, we used a series of queries in the database to summarize detection and non-detection data in encounter history files that could be used to estimate occupancy and detection probability for each species. Photographs taken of each survey location and representative photographs of each quad were downloaded onto laptops and labeled with quad name, location name, and date.

For each reptile search area, the area surveyed was delineated in GIS and estimates of total area surveyed were populated back into the database. We also used GIS to populate descriptive statistics for each survey location such as elevation, percent ReGAP habitat cover type within 100 meters of each survey location, and land ownership (public or private).

Data Analysis

We used single-season occupancy models to estimate the proportion of sites occupied (psi) and detection probability (p) for each species detected by the four different survey methodologies. Analyses were simplified to a single-season probability-based model (MacKenzie et al. 2002, 2005, 2006) with psi representing the probability that a site is occupied by the target species and p_j representing the probability of detecting the species at an occupied site during the *j*th independent survey of a site. Maximum likelihood methods were used to estimate occupancy and detection probability as well as the precision of these metrics (Wintle et al. 2004). Within a given season, no changes in occupancy are assumed at each site (i.e., sites are either always occupied or unoccupied by the species). However, if changes in occupancy occur randomly then this assumption can be relaxed (MacKenzie et al. 2006). Additional assumptions that apply to single-season models include: (1) detections occur independently at sites; (2) occupancy and detection probabilities are similar across sites and time, except when differences can be modeled with covariates; and (3) the target species is identified correctly.

Occupancy probability can be modeled as a function of site-specific covariates that do not change during the season (e.g., habitat type), whereas detection probability can be modeled as a function of either site-specific or survey-specific covariates (e.g., weather conditions or observer). Occupancy and/or detection probability can be measured as a function of covariates using the logistic equation:

$$\theta_i = \frac{\exp(\mathbf{X}_i\boldsymbol{\beta})}{1 + \exp(\mathbf{X}_i\boldsymbol{\beta})}$$

, where θ_i represents the parameter of interest for site i, X_i is the row vector of covariate information for site i, and B is the column vector of coefficients to be estimated. A number of habitat covariates were collected for future analysis as resources or interest permit (Table 2). The quarter-quad was considered the sampling unit for occupancy and detection estimates at both a statewide scale and within the known existing range of a given species. For each quarter-quad, we summarized species detection and non-detection information on the day of survey. Non-detection may arise if either the target species does not occupy the site or the investigator does not detect the species at an occupied site. After occupancy and detection was estimated at a statewide scale, we then used the known range of a species as a constraint to refine and inform our non-detection data. For example, a species was only considered non-detected when it was not observed at a given site and it was possible to capture the species because the survey occurred in the existing known range of the species. If the quarter-quad being sampled was outside the known range of the species and it was not detected, the corresponding non-detection data was not included in the analysis. An ArcGIS geoprocess that merged species range maps (Montana Natural Heritage Program and Montana Fish, Wildlife, and Parks 2012) and quarter-quads was used for this constraining process.

Detection data were stored in an MS Access database. A python script was used to access data tables and create encounter history files in a .txt format for each species in a given survey (Appendix II). Encounter history files for each species with detection and non-detection data were formatted such that a '1' was assigned to detections and a '0' was assigned to non-detections for each quad and day sampled for a given survey method. A python script was then used to import encounter history files into an analysis program that estimated occupancy and detection.

We used the R (R Development Core Team 2012) package RMark (Laake and Rexstad 2008) to construct single-season occupancy models for program MARK (White and Burnham 1999). We chose program MARK because it can interface with Program R and allows for single-season occupancy models as well as covariate analysis. Estimates of occupancy and detection probability were made at two different scales, the quarter-quad level (3 x 4.3 miles grid) and location level (defined as a 100-meter buffer around a survey point). By estimating occupancy and detection rates at two different spatial scales, we hoped to see changes in occupancy and detection estimates that might indicate differences in the home ranges of the species being surveyed.

We then refined our occupancy and detection probability estimates by limiting the occupancy and detection estimates to the known range of the species within the state (range-limited estimate). In essence, this estimate of detection and occupancy would indicate the likelihood of detecting a species in areas of the state that may contain suitable habitat in which a species of interest could occur. We later included location level and survey level covariates to explain differences in location-level occupancy and detection probability estimates using a competing-model based approach.

Results

Survey Summary

During the period 2008 - 2010, 3,863 individual surveys were conducted during 213 days at 3,048 unique locations within 282 quarter-quads (Table 3). The number of quarter-quads sampled represents 3% of those available for the entire state. A majority of sampling occurred on private property (51%), with additional sampling occurring on US Forest Service (16%), Bureau of Land Management (13%), state (12%), and other lands (9%).

During structured surveys, 5,806 species detections were recorded, and of those detections, 84 unique species were identified. Species were detected at most small mammal, bat acoustic, and lentic site surveys. However, terrestrial reptile surveys had lower detection rates (Table 4). For small mammal, lentic site, and reptile surveys, most detections were identifiable to a species although a few detections did not result in species identification either because there was not an accompanying or acceptable voucher specimen that could be used to verify the record or the specimen could simply not be identified to the species level. Many bat acoustic call sequences could not be definitively identified to a species and therefore were identified as 'probable' species detections. Only definitively identified bat acoustic call sequences were included as acceptable observation records for analyses (Table 4). In addition to structured survey observations, 5,912 species observations were recorded incidentally at 2,634 different locations. We detected 21 Species of Concern in Montana during structured surveys but failed to detect several others identified as Species of Greatest Conservation Need (CFCWS 2005) including; Great Basin Pocket Mouse, Northern Bog Lemming, Meadow Jumping Mouse, Coeur d'Alene Salamander, Milksnake, Smooth Greensnake, and Western Hog-nosed Snake.

The number of unique species and number of individuals of each species detected for each sample methodology varied considerably by geographic region (Figures 11a - 11d). For small mammals (Figure 11a), both the number of unique species and the total number of individuals detected in each quarter-quad was highest in southwestern Montana where Great Basin fauna come into the state, the east front of the Rocky Mountains where plains and mountain fauna's meet, and in some areas of higher topographic relief across eastern Montana where major habitat types converge. Conversely, both the number of unique small mammal species and total numbers of small mammal individuals detected was lowest in areas with the least topographic relief and habitat complexity (e.g., plains of eastern Montana). The number of unique bat species detected by acoustic surveys in each quarter-quad (Figure 11b) was reasonably high (7 to 9 species) across most of the state, but was low (less than 5 species) in eastern Montana north of the Missouri River where tree and rock outcrop roost sites are very limited on the landscape. The number of unique amphibian and aquatic reptile species detected at lentic sites in each quarter-quad (Figure 11c) was highest (commonly 6-7 species) across most of eastern and northwest Montana, but relatively low (often less than 4 species) across the northwestern Great Plains and in southwest Montana; landscapes that are relatively dry where habitats have been extensively modified for agriculture. The number of unique terrestrial reptile species detected in each quarter-quad with visual encounter surveys (Figure 11d) was relatively low (almost always less than 4) across the state and visual encounter surveys failed to detect terrestrial reptiles across most of western Montana.

The average amount of time spent surveying varied by survey method (Table 3). Because small mammal trap lines and bat acoustic detector surveys were overnight efforts, those surveys lasted for longer periods of time (851 and 750 minutes, respectively) when compared to lentic site and terrestrial reptile surveys which were discrete events lasting an average of 34 and 45 minutes, respectively (Table 3). Forest and woodland habitats accounted for both the highest number of unique small mammal species detected (30) as well as the highest number of small mammal individuals detected (359) (Table 5). Semi desert, shrubland and grassland, and forest and woodland habitats accounted for both the highest number of unique bat species detected and numbers of bat passes (Table 5). For small mammal trap line surveys, the total number of captures differed by trap type and species (Table 6). Museum Specials accounted for the highest number of captures (619) and had the highest success rate per trap set (6.6%), whereas track plates, which were only used in 2008, were the least productive with four captures and a detection rate of 1.4%.

Occupancy Estimates

We estimated occupancy at the quarter-quad level for each species captured at two different spatial extents, a statewide extent and within the boundaries of the known range of each species in Montana (range-limited estimate) (Tables 7 and 8). We also estimated occupancy at the location level within the boundary of the known range of each species in Montana (Figures 12b – 17b). A lack of repeat detection data prevented the estimation of occupancy at the quarter-quad level for many species (e.g., ground squirrels, weasels, skunks, Bushy-tailed Woodrat, Ord's Kangaroo Rat, Preble's Shrew, Merriam's Shrew, Eastern Red Bat, Yuma Myotis, Spotted Bat, Eastern Racer, Northern Alligator Lizard, Spiny Softshell, and Rocky Mountain Tailed Frog.

Occupancy estimates varied significantly by species and by survey method. For both statewide and range-limited estimates of occupancy (Tables 7-8) at the quarter-quad scale, Deer Mouse had the highest estimate of occupancy for small mammal trap line surveys. The occupancy estimate for Deer Mouse was 93.3% at the quarter-quad scale and 75.6% at the location level. For bat acoustic detector surveys, several species had occupancy estimates near 80% within their known range in Montana at the quarter-quad scale, including Hoary Bat, Little Brown Myotis, Pallid Bat, and Silver-haired Bat; although Pallid Bat had wide confidence intervals. Fringed Myotis and Townsend's Big-eared Bat had the lowest occupancy estimates within their known range in Montana at the quarter-quad scale, at 13.1% and 2.2% respectively.

For lentic site surveys, estimated occupancy rates within the known range of species (Table 8) were highest for Long-toed and Barred Tiger Salamanders and Woodhouse's Toad, although the estimates for Long-toed Salamander and Woodhouse's Toad were imprecise. American Bullfrog, Great Plains Toad had the lowest occupancy estimates within their known range. Occupancy estimates for terrestrial reptile species encountered during reptile area search efforts indicate that Greater Short-horned Lizard had the highest point estimate of occupancy within its known range, although the estimate was very imprecise. Occupancy estimates were not obtainable for five of the eleven species encountered during reptile area search surveys due to a lack of repeat detections.

Detection Estimates

We estimated detection probability at both a statewide extent and within the boundaries of the known range of the species within Montana (Tables 7-8 and Figures 12a – 17a).

We found that detection probabilities varied greatly between species and species groups. For example, most shrews and voles had detection probabilities less than 0.6, whereas Deer Mouse and some bat species had much higher detection probabilities. Species such as Long-tailed Weasel, Northern Flying Squirrel, Ord's Kangaroo Rat, and Striped Skunk that were not the focus of survey efforts had detection probabilities less than 1%. As a group, terrestrial reptiles had the lowest detection rates, with detection probability estimates generally less than 0.2.

Estimates of detectability for bat acoustic detectors had the tightest confidence intervals when compared to other types of surveys. Hoary Bats had the highest probability of detection at 63%, whereas Yuma Myotis and Spotted Bats had detection rates near 1%.

Range Extensions

The data collected through this work expanded the known range for the following seven species: Dusky or Montane Shrew, Pygmy Shrew, Fringed Myotis, Eastern Red Bat, Pallid Bat, Southern Red-backed Vole, and Montane Vole.

Discussion

Results of our occupancy and detection analyses suggest the single-season survey methodology presented herein can serve as an effective monitoring tool for most bats, small mammals, reptiles and amphibians. We found that the methods described were most appropriate for estimating occupancy of these animals when detection probabilities were greater than ten percent. Most of the species for which estimates of detection probability were less than one percent were not the focus of surveys (e.g., most squirrels and rabbits, weasels, skunks, Bushy-tailed Woodrat). However, a number of target species also had detection probability estimates of less than one percent, including many terrestrial reptile species, Ord's Kangaroo Rat, Preble's Shrew, Merriam's Shrew, Eastern Red Bat, Yuma Myotis, and Spotted Bat. Detection probabilities for these species were low because repeat detections rarely occurred at individual sampling locations. The lack of repeat detections for these species or groups of species suggests that alternative or additional sampling methods may be more appropriate for detecting presence. However, considering that we detected 29 of 38 small mammal species that were targeted for survey (i.e. excluding ground squirrels, tree squirrels, lagomorphs, and mustelids), 14 of 15 bat species, 12 of 17 targeted reptile species, and 12 of 13 targeted amphibian species during this project, the methodologies presented herein provide an adequate framework for broad-spectrum detection of a majority of target species in Montana.

Detection probability estimates for many of the bat species were high and precise, indicating that acoustic survey is a good method for monitoring the status of many bat populations.

Reptile occupancy estimates were plagued by a lack of repeat detections at locations by multiple observers. Because detection estimates were generally low for many species encountered during reptile surveys, occupancy estimates were only obtainable for six of the twelve species encountered and were not as precise as those obtained for other taxa. For these taxa, alternative methodologies, such as drift fences and funnel traps, may need to be investigated with future efforts to see if detection rates can be increased in order to provide more precise occupancy estimates.

The ratios of detection-corrected point estimates of occupancy to naïve occupancy rates for species detected in this study (Figures 17a-d), clearly show the value of replicate surveys in estimating true occupancy rates. Although naïve and detection-corrected occupancy estimates were similar for some species (e.g., Deer Mouse and other common small mammal species), estimates of true occupancy were often double naïve estimates for many species and ranged up to 10 times higher than naïve rates for some. Animal behavior, vegetative cover, weather, and observer skill likely contributed to some differences in detection. However, low detection probability estimates for some non-target species was due to the fact that the mouse, Sherman, rat, and pitfall traps used in this effort were inappropriate for detecting some of the larger small mammal species (e.g., lagomorphs, ground squirrels, mustelids).

Detection probability for each species, survey type, and trap type should therefore be a major consideration when estimating site occupancy. Table 7 provides baseline detection and occupancy estimates against which future sampling efforts should be compared.

Preliminary results (not shown in detail in this report) of a competing model based framework for assessing the importance of various covariates on occupancy suggests that the presence of certain species and or species groups may be influenced by a variety of habitat factors. In general, the covariate with highest predictive capability for small mammals was elevation. However, many of the competing models failed to out compete the null model of constant occupancy across the landscape. Bat models similarly appeared to be driven by elevation, although the occupancy of numerous species was sometimes best described by an interaction model that considered dominant habitat type and elevation. Occupancy models for amphibian species seemed to vary somewhat by species, with some being best described by grazing variables, maximum water depth, or elevation. For species that were best described by maximum water depth, the optimal depth was typically a maximum water depth less than one foot. More analyses could be conducted with this data set and the large number of variables measured.

Although an effort was made to sample all habitats with equal proportion, native habitats were sampled more frequently than non-native habitats. Results of both small mammal trap line surveys and bat acoustic detections surveys highlight the importance of forest and grassland habitats for bats and small mammals. Numbers of species and numbers of detections were highest where the dominant cover type was identified as forest and woodland habitats, with shrubland and grassland habitats a close second.

Conclusions

This project developed and refined survey, inventory, and monitoring protocols in order to better understand the distribution, status, and habitat requirements of species and species groups identified as most in need of inventory within Montana (Montana Fish, Wildlife, and Parks 2005). It was our hope that development of effective and standardized methodologies would allow other state, federal, tribal, and private entities to follow our lead and gather compatible data for these species groups. In fact, we have been very pleased that both the Bureau of Land Management and U.S. Forest Service have begun to use these protocols during recent survey efforts. We hope that the use of these protocols will become more widely adopted in the future since use of common protocols allows the distribution and status of species to be more easily assessed over time.

The project simultaneously provided baseline information on species’ distributions, site occupancy rates, and detection probabilities that will be used to inform current species’ conservation status ranking and management efforts. The information gathered will serve as a statewide baseline to assess changes in the distribution and status of these species over time related to changes in habitat and/or management efforts. The fact that the number of records in the statewide animal observation database was doubled, or in some cases tripled, for many species during the course of this project and that the known ranges of seven species (Dusky or Montane Shrew, Pygmy Shrew, Fringed Myotis, Eastern Red

Bat, Pallid Bat, Southern Red-backed Vole, and Montane Vole) were extended through this work is significant and has important consequences for their current and future management.

We believe the methodologies developed during the course of this project provide an adequate framework for broad-spectrum monitoring of a majority of target species in Montana considering that we detected 29 of 38 small mammal species, 14 of 15 bat species, 12 of 17 reptile species, and 12 of 13 amphibian species that were targeted for survey during this project. The fact that estimates of true occupancy were often double naïve estimates for many species, and ranged up to 10 times higher than naïve rates for some, really emphasizes the importance of the repeated sampling methodologies developed with this effort in order to estimate detection probability and true occupancy rates. The baseline detection and occupancy estimates in Table 7 are valuable baselines for planning and executing future sampling efforts and measuring changes in the status and distribution of species over time.

Although we detected 21 Species of Concern using these standard broad spectrum survey methods, we failed to detect several others identified as Species of Greatest Conservation Need (Montana Fish, Wildlife, and Parks 2005) including; Great Basin Pocket Mouse, Northern Bog Lemming, Meadow Jumping Mouse, Coeur d'Alene Salamander, Milksnake, Smooth Greensnake, and Western Hog-nosed Snake. We recommend focal rangewide surveys for these species in order to assess their status when and where they are most active and detectable.

Finally, we encourage more complex analyses of the datasets gathered during this effort. Specifically, more in depth analyses of the effect of habitat covariates on species detection and occupancy rates should be conducted to better inform habitat management efforts.

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